Thunderstorm Phenomena in Ceylon

IT has become natural to associate rainfall in Ceylon with the Monsoons. Perhaps this is understandable, because the greatest proportion of rain falling (in terms of amounts) in the Island is that produced by the Monsoonal currents. It has also become commonplace to refer to the island's climate as being Monsoonal. But from a climatological point of view it is erroneous to accept these attitudes: firstly, to consider the Monsoonal characteristics as being typical and in synonymity with climate, and secondly, to associate rainfall in the island with the Monsoons only. The Monsoon, in fact, does not refer to the rainfall associated with it, as is assumed by the average layman. Considered from a meteorologic point of view, the Monsoon is essentially and basically a 'wind' with characteristic opposite-seasonal direction of blowing; the rainfall accompanying it is but incidental and not necessarily a Monsoonal attribute.[1] Further, it is assumed that the island's typical weather phenomena is Monsoonal; this again, is incorrect climatologically. Basically, from the standpoint of the island's latitudinal situation it is the convectional weather phenomena that is typical.[2] It is only when other weather phenomena produced elsewhere invade the island's atmospheric environs that this convectional activity is lessened to such an extent so as to be almost absent; the Monsoon, the Tropical Cyclone and other weak depressional activity are such ' foreign weather importations '. It is during the period of convectional activity, namely during the months of March-April and October that all over the island, thunderstorm phenomena are dominant. During the dominance of the respective Monsoonal currents convectional activity and therefore thunderstorm phenomena are confined to the areas least affected by the Monsoonal currents; on the eastern side of the island during the South-west Monsoonal period (May to September) and on the western side during the North-east Monsoonal period (November to February). However, it must be mentioned that this is more true during the South-west rather than during the North-east Monsoonal period.

The thunderstorm to the layman brings to mind the phenomena of sudden heavy short-duration rainfall accompanied by gusty winds, thunder and lightning. Perhaps, he has also noticed that such phenomena seem to be confined to certain periods of the year, notably in March, April and October. From a meteorological and climatological standpoint, the island is typically located,

1. *Meteorological Glossary* (London : Air Ministry, 1940), 134. For detailed consideration refer, George Thambyahpillay, *Climates of Ceylon*: M. A. Thesis (Univ. of California, 1952), 59-65.

2. Thambyahpillay, op.cit., 65 ; 72-76.

so as to be a regular source of thunderstorm activity.[3] However, as mentioned earlier certain meteorologic conditions over the Indian sub-continent and the South-East Asiatic environs transmit their influence to the island's atmospheric environment so as to modify and vitally nullify the normal weather sequence. Thus are created the weather anomalies of the island in the form of depressions, cyclones and Monsoons. A detailed analysis of thunderstorm activity in the island must be preceeded by a consideration of the typical meteorologic conditions that would render the day potentially a thunderstorm-day .

Let us consider a typical day in the months of March, April or October; insolation performs its dominant role. The incoming solar short-wave radiation is partly lost to the upper atmosphere, and partly absorbed by the gases and particles in the lower atmosphere and by the earth's surface. The rapidly heated land surface, begins to transfer the heat by the processes of conduction and radiation (to the surface air). The air above the surface gets heated and with its newly acquired thermal character becomes of low density; it will therefore seek to reach areas of similar density. Thus begins the initial vertical movement of a mass of air. When air begins to indicate a tendency for vertical ascent, it is said to be *unstable.*[4] This, *unstable* air to begin with, is ' dry ', though it does contain water vapour ; it is termed ' dry ' meteorologically, because it does not contain the optimum amount of water vapour that it has the capacity to hold, in terms of its temperature.[5] The higher the temparature

3. Latitudinally the island is situated so as to receive high insolation throughout the year ; further, no part of the island is more than 65 miles from the coast, so that the influence of the cool sea breeze is felt far inland.

4. Air that is *stable* does not acquire vertical ascent *in situ*, unless induced by some mechanical or thermal agency. It is found that temperature decreases with increasing altitude ; this seems, at first a meteorological paradox, but is easily explained. At upper levels, the atmosphere is free from many of the impurities such as dust, water vapour, etc. which act as insolation absorbing media ; these are either naturally or artificially induced material and form a fair proportion of the lower atmosphere. The freer upper atmosphere therefore forms simply a media for the insolation radiational waves to pass through. Thus temperature decreases towards the upper levels of the atmosphere. This change of temperature with change in altitude is termed the *lapse rate*. The normal *lapse rate*, i.e., decreasing temperature with increasing height is termed the *environmental lapse rate* and amounts to about 3·3°F/1,000 feet. When a mass of air acquires a *lapse rate* more than the *environmental lapse rate* it begins to displace itself vertically. *Stability* and *instability* are of various types, but no detailed discussion will be made here, because of the technicalities involved.

5. The water vapour carrying-capacity of air is a function of temperature ; the higher the temperature the greater is the capacity for it to hold water vapour. *Absolute humidity* refers to the total water vapour present in a mass of air and is expressed as an amount of grains ; *relative humidity*, on the other hand, is the amount of water vapour present expressed as a per cent of the water vapour-carrying capacity of the air at the particular temperature.

0°*F*	*Water vapour carrying capacity (grains)*
30	1·9
40	2·9
50	4·1
60	5·7
70	8·0
80	10·9
90	14·7
100	19·7

As the temperature increases, the 'carrying capacity' also increases in greater proportions ; thus while between 30°F and 40°F the capacity is only 1·0 grain, between 90°F and 100°F it is as high as 5·0 grains.

of the air the greater is its capacity to hold water vapour; absolute humidity therefore is a function of temperature. When the air contains the optimum amount of water vapour, then it is said to be *saturated.* The air, that is *unstable* and therefore ascending will do so at a certain *lapse rate* which, when the air is dry is termed the *dry adiabatic lapse rate.*[6] This process of vertical ascent of unstable air is technically termed *convection;* in other words, the air acquires turbulence and overturning. Convectional currents are therefore the product of thermal characteristics of the immediate surface from which the air ascends; shimmering surfaces (metal roads, surfaces, bare rock surfaces and sandy areas) indicate the process of convectional activity. The air ascending at the DALR would also begin to cool as it reaches higher altitudes and therefore lower thermal layers. The cooling of the mass of air would involve the release of heat that it possesses. Since the heat released is latent within the rising mass of air, this process of cooling is termed *adiabatic.*[7] The air mass is now rising to higher levels and is cooling adiabatically in the process; however, the air is no more as dry as it was during its initial stage of ascent, because the temperature is lower and the optimum water vapour-carrying capacity is lowered. Thus, the cooling air mass becomes more moist though the absolute amount of water vapour has not increased; the absolute humidity (actual amounts of water vapour) has not changed, but relative humidity has remarkably increased (i.e., humidity in terms of temperature). A stage will soon be reached in the process of ascent when the air mass at its new temperature becomes *saturated*; in other words, the air mass has now reached the stage when in terms of its temperature it holds the optimum, in terms of water vapour-carrying capacity. This moist or *saturated* air will now acquire a new *lapse rate,* namely the *saturated adiabatic lapse rate* (*SALR*).[8] Any more cooling by ascent would mean the release of the excess water vapour from the air, which would now be considered to be *supersaturated.* This process of release of excess water vapour is

6. Henceforth it will be designated DALR; correspondingly the *saturated adiabatic lapse rate* would be SALR. The rates are as follows :—

DALR : 5·6°F/1,000 feet

SALR : 2·8°F/1,000 feet

7. A process is said to be adiabatic when no heat is added to or withdrawn from, the air that partakes in the process. In other words the heat required to ascend vertically is latent within the air and when cooling takes place this heat that is latent is released; thus, warming and cooling processes are performed adiabatically.

8. For detailed consideration of the thermodynamic principles involved, see Petterssen, *Introduction to Meteorology* (New York : McGraw-Hill, 1941), 49-79.

termed *condensation*[9] forming clouds. For condensation to be effective, there must be present in the air *hygroscopic particles or nuclei*[10] to absorb the released water vapour. However since condensation releases latent heat (of vaporisation) and therefore increases the air temperature, the tendency would be to make the air relatively drier. Thus these two processes—cooling (condensation) and heating (latent heat release) tend to counteract each other. Thus, in order to maintain the process of condensation it is indispensable that the air should be cooled to such a degree so as to counteract the heating process. This would mean the need for *supercooling* the air.

When condensation takes place at lower levels of the atmosphere, the typical cloud developed is that termed *Cumulus.* This cloud type is easily recognised because of its dome shape or rather cauliflower character. During the months of March, April and October, these cloud types are familiar phenomena in the Ceylon Sky. Their initial development takes place as soon as the insolation process becomes to be effective in producing convectional currents. By the early afternoon the sky is characteristically patterned with these clouds. The process of convective activity is too familiar a phenomenon in Ceylon and thus does not warrant a detailed description here.[11] The characteristic Sea breeze phenomenon is a further indication of the effective operation of convectional circulation. Land and sea bodies possess different heat coefficients and

9. In simplified form, clouds may be classified in terms of altitude : thus high clouds are the *Cirrus* types, the medium high clouds the *Alto*-types (Alto-stratus or Alto-cumulus) and low clouds, the *stratus.* The Cumulus clouds are convective clouds that exhibit vertical development and may reach the levels of the *Cirrus* zone, when in combination with them, the term *Cirro-cumulus* is applied. Condensation can occur even at surface levels and all forms of mist, fog, etc. are really ' surface cloud formations '. Even in the University Park, condensation is a characteristic phenomenon during the mornings following a cloudless, starry night. Here because of the rapid nocturnal terrestrial radiation, (the heat of the surface is radiated back to the atmosphere and if clouds are absent this long-wave radiation process goes unimpeded) the surface gets ' chilled ' and so the air higher above is relatively warmer than the surface and the air close to it; thus is caused ' ground fog or mist ' in the University Park. As soon as the air begins to be heated after sunrise, the mist gradually ' dissipates '. Dew, also results from condensation due to surface saturation.

10. Not all particles of dust can absorb water vapour. To be *hygroscopic* the nuclei must posses affinity for water. Such nuclei occur in the form of calcium chloride and sodium chloride particles (salt in sea spray) and various sulphates (products of combustion). Sulphur dioxide resulting from the burning of fuels, oxidises the air and forms hygroscopic nuclei of sulphur trioxide. On the average, a cloud droplet contains one part hygroscopic material to 10,000 parts of water by weight. The size of this nucleus may be realized when it is known that while a nucleus is at most 2 microns in diameter, the cloud droplet is 40 microns and a raindrop varies from 500 to about 4,000 microns (i.e., 0·5 to 4 mm.).

11. However see Thambyahpillay, op. cit., 72-76 for a detailed description. The writer has had occasion to observe these phenomena from Adam's Peak as well as from the Western coast.

thus in the early afternoon the moist cool air from the ocean blows inland to take the place of the heated and ascending air over the coast and central highlands of Ceylon. This ascending air cools adiabatically and is wafted in the form of cumulus clouds towards the coast in the late afternoon and evening. Now the Land breeze sets in, i.e., the sea is relatively warmer and therefore the wind from the land blows towards the sea to take the place of the warm air ascending from the warmer sea surface. But, before these clouds (convective cumulus clouds) make their eastward and westward journeys from the central highlands of the island, they may precipitate to produce rain.[12]

All clouds would not necessarily give rain ; Cirrus and Alto-Stratus clouds can generally be considered non-rain bearing clouds. But our context-Ceylon-being a tropical environment it is the convective clouds namely the Cumulo-types that are more significant and are potentially responsible for thunderstorms. However all Cumulus clouds may not necessarily develop into rain-bearing clouds. As the process of condensation continues—the original flat based cumulo-clouds begin to 'grow' vertically producing a towering effect. Small scattered Cumuli gradually coalesce into larger ones and begin to develop 'towers'. From the onset of this *towering* process the original fair weather Cumuli acquire rain-potentiality.

Hence the saying,

'When clouds appear like hills and towers,
The earth's refreshed by frequent showers'.

Let us visualize the 'mechanics' of the process of condensation and eventual precipitation within a cumulus cloud. A highly pregnant cumulus cloud developing into a cumulo-nimbus cloud under certain favourable conditions is the ultimate thundercloud producing the 'storm'. From the initial condensation stage onwards the hygroscopic nuclei absorb the water vapour from the air. The growing nuclei would cause further condensation to occur ; but, the growing rain-drops become less effective hygroscopic nuclei. In fact, smaller rain-drops grow at a faster rate than the larger drops ; it has been computed that, while it takes a condensation nucleus only 100 seconds to grow to an average cloud droplet, it would take almost 24 hours for the cloud droplet to grow to the size of an average rain-drop. The rain-drops do not 'grow' through continued condensation ; they do so by the process of coalescence of small cloud droplets. With the 'towering' process reaching, to over 15,000 feet above the surface, *supercooling* takes place and consequently water droplets solidify into ice particles. Thus at temperatures between 20° F and 0° F, the cloud generally consists of ice particles or water droplets mixed with ice particles. The process

12. These are the typical convective showers. The daily 'procession' of the convective cumuli from the central highlands towards the coast is a familiar phenomenon observable from the University Park.

of precipitation therefore requires initially the stage of coalescence of cloud droplets into large rain-drops ; if the process of coalescence is absent, the cloud is technically considered to be *colloidally stable*[13]. The coalescence of cloud droplets is therefore the result of what is termed *colloidal instability*. The latter is a function of five basic conditions, namely :—

(i) *Electric charges of the droplets* : each cloud droplet acquires an electric charge—positive or negative. When neighbouring droplets possess opposite charges, they naturally are attracted, leading to coalescence ;

(ii) *Size of the droplet* : it is found that the saturation vapour pressure varies slightly with the curvature of the water surface ; the larger the drop the lower the saturation vapour pressure. The smaller drop tends to evaporate and would condence on the supersaturated larger drop ;

(iii) *Temperature of the droplet* : saturation vapour pressure varies with temperature and increases with rising temperature This is of great significance in tropical latitudes because of the higher temperatures. In the turbulent cloud, the colder droplets from above in their descent would meet the warmer droplets ascending from below. *Supersaturation* would take place over the colder droplets and *subsaturation* over the warmer droplets ; this would mean the growth of the colder droplets at the expense of the warmer ones;

(iv) *Motion of the droplets* : turbulence may cause coalescence by collision of the droplets ; this is however, found to be not a necessary condition.

Bergeron observed that these four conditions were not necessary for precipitation to take place ; that in spite of the prevalence of these conditions, precipitation did not necessarily follow. Therefore he postulated the really significant condition, namely :—

(v) *The presence of ice crystals* : it is considered that *colloidal instability* could be readily induced in a cloud in which are present a mixture of *subcooled* water drop-lets and ice particles. The difference in the saturation vapour pressure of the *subcooled* water droplets and ice crystals would result in the relative evaporation of the water droplets ; this would in turn condence on the ice particles. These ice particles by a process of such accretion would become heavier and begin to fall through the cloud ; in this process of 'falling through' the ice crystals would collide with water droplets leading to further coalescence. This 'collision-coalescence' process would occur until the crystals leave the cloud mass. These crystals as they descend towards the earth's surface would begin to melt because of the higher temperature and would reach the surface as rain only if they can counteract the ascending warm air currents.

This theory of precipitation of Bergeron is widely accepted as the best explanation. However, it has also been observed in tropical latitudes that, because

13. Since technical details have to be kept to a minimum, detailed consideration will not be made as to the character of *colloidal stability and instability*.

of the high temperatures prevalent, turbulence can bring about a mixing of the colder and warmer water droplets, which would result in precipitation. But such showers are very light and are of very short duration. These showers are not predictable, because the cumulus clouds do not exhibit 'towering' character. Very often these showers occur when the sun is shining brightly and baffles the layman; this meteorologic anomaly is understandable, for the low cumulus clouds would be regionalized to give the highly localized showers. This is the so-called 'all-rain' theory as opposed to the 'ice-crystal' Bergeron theory. Bergeron's theory also explains the sudden release of rainfall; as long as the cloud consists of only water droplets resulting from condensation, the cloud is *Colloidally stable.* Such clouds are typically observable in the island. Very often despite the overcast sky with dominant alto-stratus and alto-cumulus clouds rainfall does not occur: this often baffles the layman not conversant with simple meteorologic understanding. When the cumulus clouds build up and 'grow' into towering formations, to reach a ceiling of over 15,000 feet, ice crystals form and the *colloidally unstable* clouds would suddenly release their abundant 'burden' resulting in the squally and intense deluge. For, as Sir Napier Shaw put it, 'it is a gigantic, if comparatively slow, explosion of moist air, the latent heat of the moist air acting as fuel'.

The stage in the gradual 'growth' of the simple, fair-weather cumuli into the 'towering' cumulo-nimbus clouds, with anvil development to finally produce the thundercloud is easily observable in the island on almost any day during the aforementioned convectional months, i.e., March, April or October. In Figure 1, an attempt has been made to portray the stages 'in the' genesis and dissipation of the cumulus cloud during any convective day in the island.

Fig. 1—Convective Cloud Types[14]

(*a*) These are the flat, non-towering cumuli, noticeable on any day in Ceylon (when the Monsoonal or the Cyclonic weather phenomena are absent). These are well separated with little or no tendency for 'vertical growth' or for 'coalescence'. These cumuli ('cumulus humilis') portend fair weather and are indicative of the stability of the atmosphere above the condensation level. If, by the early afternoon such cumuli show no tendency to 'tower' then they positively portend no rain in the evening. These cumuli, therefore are composed only of water particles without 'ice-crystal' development.

(*b*) The second stage, if developed, gives the cauliflower 'towering' effect and is the typical cumulus cloud type. Though this cloud

14. The writer would be glad to illustrate with colour slides the stages in the development of these convective cloud types.

stage is also not a rain-potential (because water droplets still form the composition of the cloud) it might develop into the third stage (*c*); unlike the cumuli of the (*a*) type, these exhibit signs of 'growth'.[15]

(*c*) Here, is a further stage in the cumulus development with the 'scarf' being the characteristic feature; the 'scarf' usually consists of water droplets, though ice crystals may also be present. The 'scarf' is indicative of the transition from the fair-weather cumulus to the potential rain-bearing cumulo-nimbus cloud.

(*d*) The progressive development of the cumulus has now reached the 'rain-cloud' stage. The 'growth' vertically has ceased and the 'towers' dissipate and begin to 'flatten out'; this 'flattening process' indicates the 'crystallisation of water droplets' into ice due to cooling in higher levels. The cloud ceiling may be over 15,000 feet. This is the 'penultimate' stage of the convective cloud and precipitation would naturally result. This type of cloud is termed cumulo-nimbus calvus or bald cumulo-nimbus. The nimbus character of the cloud is easily observed by its 'dark and ominous looking' nature.

Trinculo: '. . . ; yond same black cloud, yond huge one,
looks like a foul bombard that would shed his liquor . . .
. . . yond same cloud cannot choose but fall by pailfuls . . .'

Act II, Scene II, *The Tempest* (Shakespeare).

(*e*) This is the 'ultimate' stage of the convective cloud, namely, the thundercloud and technically termed cumulo-nimbus incus or cumulo-nimbus with anvil. The 'anvil' is the clue to the 'deluge' to come; an anvil develops when it is composed of ice crystals. Thus, this stage is imminently rainy; the thunderstorm finally is 'mature' and is marked by the sudden, squally intense rainfall, accompanied by thunder and lightning.

(*f*) The final stage is the gradual dissipation of the thundercloud. This cloud stage termed the strato-cumulus may also result immediately after the fair-weather cumulus stage, when a sheet of high cloud develops above them. The strato-cumuli are sure indications of the atmosphere developing a stable stratification; thus they portend potential non-rainy spells.

15. These 'towering cumuli' are responsible for the 'bumps' that are experienced by the pilots flying on the Colombo-Kankesanturai and Colombo-Gal Oya routes.

In forecasting the potential weather during the months of convectional activity, observation of the cumuli (clouds) with special attention to the progressive development of the 'top' surface warrants very good results;[16] 'towering' is an indication of a potential rainy spell.

Fig. 1—Vertical section through convective thunderstorm

Cu : Cumulus clouds
M : Mammatus clouds
A : Anvil top of cumulo-nimbus cloud
P : Protruding anvil cloud
G : Strong gusts
U : Updraft (warm air currents)
D : Downdraft
R : Primary rain or hail area (initial sudden shower)
R' : Secondary rain (continuous rain but less intense, sometimes drizzle)
Z : Freezing isothermal level (O°C/32°F)
W : Wind direction.

The thunderstorm may be considered to be an 'overgrown', intensely colloidally unstable cumulo-nimbus cloud. Two basic meteorologic conditions are indispensable for the genesis of thunderstorms: intense insolation resulting in high temperatures and high humidity produced by rapid adiabatic cooling of the vertically ascending air currents. The first condition is fulfilled in Ceylon during the equinoctial periods, i.e., March-April and September-October;[17] the second requirement is necessarily a result of the first and therefore is automatically present. These two conditions, form the *raison d'etre* of intense thunderstorm activity during the afore-mentioned months and also of their marked development during the hottest days. A consideration of the 'mechanics' within the thunderstorm reveals interesting features. The 'thunderstorm' is the 'ultimate' stage in the development of the simple convective cumuli, provided that meteorologic conditions are present facilitating the gradual 'growth of the towers' and eventual ceiling development to over 15,000 feet. Within the cumulo-nimbus cloud the ice particles tend to constantly fall towards the earth's surface; in these attempts they melt into water drops (rain-drops) on leaving the cloud and entering the warmer atmosphere. But, in order to

16. Forecasting weather from the observation of convective clouds is gained by following simple rules and experience. The favourable geographical situation of the University Park permits very satisfactory observations to be made.

17. However, it must be mentioned, that in reality in September, convective activity is not dominant because of the still weakly persisting South-west Monsoonal currents. Further, a short 'lapse' period is observed in equinoctial insolation and is reflected in the island's weather periods. See Thambyahpillay, op. cit., Chapter III, Part A, 24-46.

finally reach the earth's surface as rain, these must be of such size and weight so as to overcome the ascending currents of air; thus, before a single rain-drop reaches the surface of the earth it must have undergone a series of descents and ascents. It has been computed that if the drops grow larger than 4 mm. in diameter, they will fall with a velocity of 8 metres per second (about 27 feet per second). The drops then break into smaller drops and fall slowly. But, if the ascending air currents reach a velocity of over 8 metres/sec., then the drops are split up into smaller ones and will be carried upwards by the air currents. These drops will now acquire more moisture probably by crystallization into ice and thereby leading to water droplets condencing on the crystals; the latter then begin to fall through the cloud and into the atmosphere. In Figure 1, is reproduced a vertical section through a convective thunderstorm according to Haynes. The characteristic features are the strong updrafts and downdrafts; while the updraft is initially responsible for the 'growing' thundercloud, the strong downdraft is the cause of the heavy rainfall reaching the earth's surface. This fall of rain is so vigorous that it has become natural to refer to 'thunder-showers' rather than to 'thunderrains'. The intensity of the thunderstorm rain varies from about ten minutes to well over an hour or two,[18] depending on the degree of 'convectivity' attained in the locality. However, because of the diurnal temperature variation, the land-sea breeze phenomena determine the movement of the thunderstorm. Thus, the thunderstorm precipitating over the Kandy environs in the early afternoon or late afternoon, would reach the western coast between 3 p.m. and 6 p.m. accordingly.

The 'shower' is not the only attribute of the thunderstorm; perhaps the more fascinating and noteworthy to the layman are the *thunder and lightning*. From a meteorologic viewpoint, there are other phenomena namely the *squall wind*, and *hail*.

Lightning and thunder: These two phenomena occur simultaneously, but thunder is preceeded by lightning, because of the difference in the speed of travel of these two phenomena—namely light and sound. As rain-drops grow in size, they reach a stage of growth, when no more cohesion is possible; further attempts to 'grow' would result in the splitting up of the rain-drops. The larger drops continue to fall towards the lower levels of the cloud and remain there, or fall as rain; the smaller drops, on the other hand, are carried into upper

18. To mention a few observations in the University Park: on the 27th of March the thunder-shower suddenly occurred about 4-20 p.m. and the intense fall ceased by 4-45 p.m., while drizzle continued till about 5-30 p.m. Widely spread strato-cumulus heralded the clearing sky. The shower on the 25th of March was very intense and lasted for about two hours from 9-00 p.m. The fore-and afternoon of 31st March was unusually warm and the 'growing' cumuli finally precipitated by about 2-30 .m.; after 3-30 p.m. drizzle continued till about 4-30 p.m. The *squall wind* was very noticeably marked.

levels by the ascending currents. These drops—the smaller and the larger—would posses different electrical charges ; the larger ones carry positive charges and the smaller ones negative charges, while the earth itself is usually of negative charge. Continued development of the charges leads to the discharge of electrical currents in the form of a flash of lightning. These lightning flashes may be either between neighbouring oppositively-charged clouds or between the earth and the positively-charged cloud. Thunder is due to the violent expansion of the air due to an extremely sudden and great increase of temperature consequent upon the tremendous heat of the lightning.

The Squall Wind : As shown in Figure 1, this wind is caused by the strong downdraft of the cool, moisture-laden air in front of the main storm. This squall wind attains great velocities and occur in gusty form. They function as 'heralds of the storm'.

Hail : Hail, is in fact, simply a form of precipitation; but, since it occurs as 'stones' or hardened globules of ice, it is a much dreaded phenomenon, because of the tremendous damage it causes to crops and even lives and property. It occurs only in the most intensely developed thunderstorm; it often baffles the layman, that 'ice globules' should fall during the hottest part of the afternoon[19] and in the tropical latitudes. The explanation, is however, simple: when convectional currents are most vigorous so as to attain velocities of about 50 miles per hour, descending rain-drops are caught up in this tremendous upsurge and are therefore carried into higher levels, where the temperature is below freezing (Figure 1). Here they mix with snow and freeze as ice globules. In their descent to lower 'rain-levels' they acquire a coating of clear ice by the condensation of the rain-drops upon them. If caught up within another updraft, they are further carried into the higher levels of freezing temperature ; they now acquire another coating of ice and this process of 'ice-layering' is continued corresponding to the 'ascent-descent' phenomenon, until they grow into larger sizes. They fall to the earth when a temporary lull occurs in the updraft, and when caught within the downdraft. The size of the 'hailstones' depends on the strength of the updraft and on the number of their 'ascent-descent' series.

19. On the 13th of March (1954) at about 2-30 p.m. an intensely developed thunderstorm precipitated hail. Though the 'hailstones' were of small diameter (about 5 mm. on the average) yet the occurrence was interesting. Since the writer was in Peiris Hall observations before the 'hailstorm' were made and showed remarkably the characteristic sequences of thunderstorm potentiality, as exhibited by the progressive cloud 'growth'. The 'hailstones' on examination revealed at most a 'dual-layering' indicating that the 'hailstones' had only a couple of 'ascent-descent' series. Examination of 'hailstones', in California, by the writer have revealed three to four layers of ice-coating. This coating occurs in the form of alternating concentric layers of clear ice and opaque layers of partially melted snow.

In resumé, it might be mentioned that from the climatologic point of view, Ceylon is latitudinally situated to be a source region of potential thunderstorm activity and should form part of the normal weather sequence of the island. However, their activity being conditioned by ideal convective circulation, they are confined to those periods of the year, when the island's weather anomalies ('Monsoons, depressions and Cyclones) are absent. The regional concentration of these phenomena depends on the weather conditions during the day (thermal and/or anomalous weather) ; during the 'advance' and 'retreat' stages of the South-west Monsoonal period, thunderstorm phenomena prevail even in the western part of the island.[20] The references in this paper, to 'thunderstorms' are to those that are characteristically associated with convectional weather conditions—which latter, the writer considers to be the climatologically warranted *normal* weather of the island.

GEORGE THAMBYAHPILLAY

20. Detailed considerations of intensity and regional occurrence of thunderstorm rain will be made in a subsequent paper entitled, 'The Rainfall Rhythm in Ceylon'. The writer here, wishes to deplore the poor appreciation by the general public of the weather reports of the Colombo Observatory. A critical study of these reports reveal the validity of the forecasts. However, the difficulties of weather forecasting in tropical latitudes must be taken into consideration ; perhaps only those who are meteorologically or climatologically inclined would appreciate this fact.

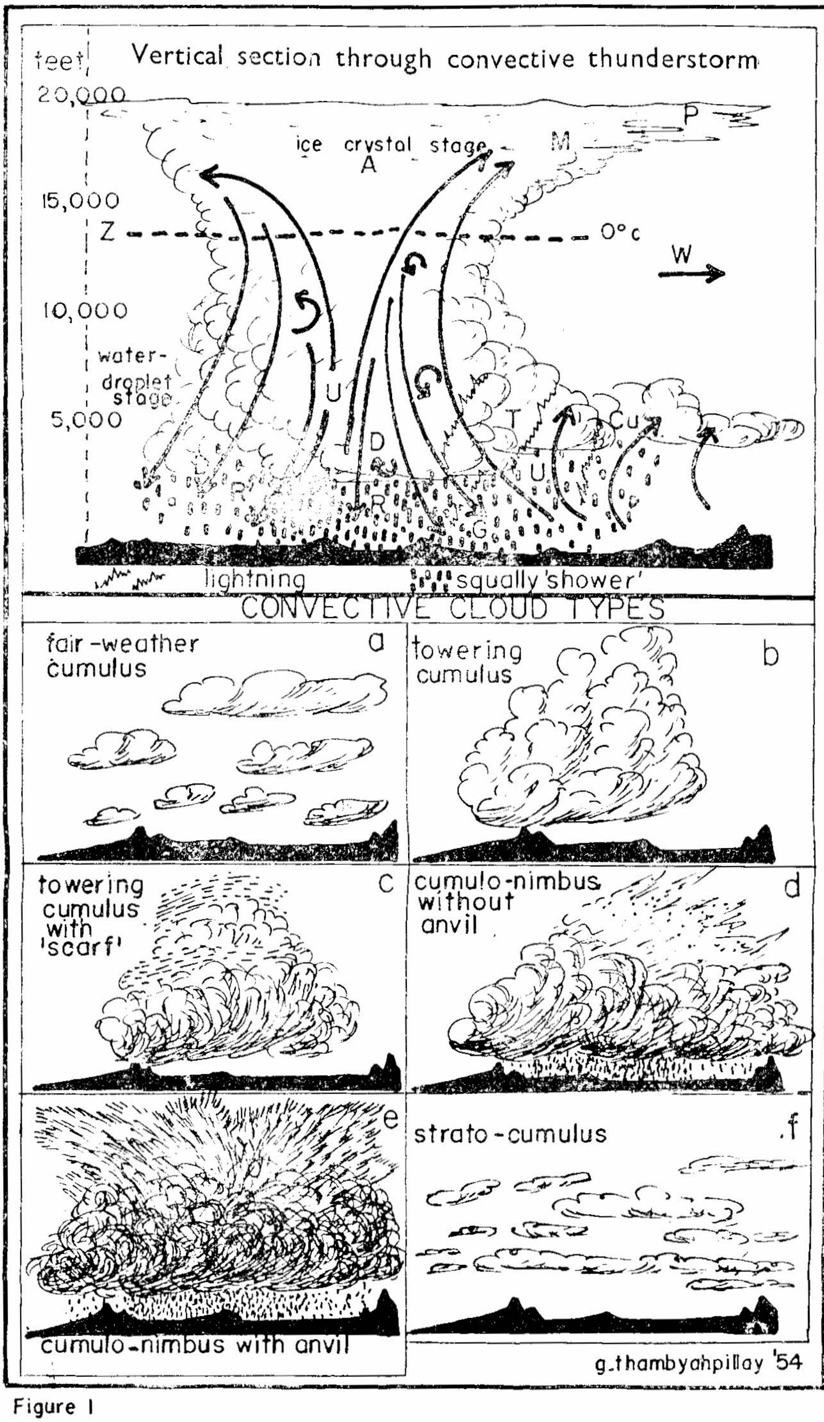
feet
Vertical section through convective thunderstorm
20,000
P
ice crystal stage
A
M
15,000
Z
0°c
W
10,000
water-droplet stage
U
5,000
D
R
T
Cu
U
N
G
lightning
squally 'shower'
CONVECTIVE CLOUD TYPES
fair-weather cumulus
a
towering cumulus
b
towering cumulus with 'scarf'
c
cumulo-nimbus without anvil
d
e
strato-cumulus
f
cumulo-nimbus with anvil
g. thambyahpillay '54

Figure I